AUTOMATED CONTROL OF NAVIGATION LOCKS

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INTRODUCTION

Increasing numbers of navigation projects are undergoing rehabilitation and upgrading of lock operations.[1,2,3] Some site managers have designed and installed systems that involve significant automation of the locking process. These changes are motivated by probable reductions in future labor resources. In recently observed cases, automated upgrades have exhibited varying degrees of success. This study examined various automated lock designs. The following sections describe some of the common trends and successful approaches observed.

GENERAL CONSIDERATIONS

The designs of the automated control systems examined in this study were tailored to the required operations and site characteristics of the projects. Some operations such as initiation of a locking event were maintained as manual control functions. At some sites, the remainder of the locking event was automated. In these cases, the control systems provided sequential actuation of the lock gates and pool elevation control valves. Site characteristics that impacted the designs included overall size, layout, access, and traffic. Larger sites which for example contained large or dual locks tended to require additional bypass or backup control features. Overall site characteristics also influence the number of closed circuit television cameras (CCTV) required to monitor site operations. One study underway is considering automation of a site that features a small traffic volume of pleasure craft. In this case, the option of remote operation of an un-manned lock is being considered.

Also subject to site characteristics is the number and location of control consoles. Each case examined herein featured a main control room located at the best vantage point and at least one auxiliary control console located in a booth along the lock wall or in another building. In some cases, backup control consoles were placed in booths adjacent to each gate of each lock at the site.

MAIN CONTROL EQUIPMENT AND INSTRUMENTATION

Hardware

A typical control system utilizes an industrial personal computer (IPC) for programming of ladder diagram logic settings and central coordination of a programmable logic controller (PLC) system. This machine may also house the main user interface.

The PLC system consists of a central processor unit (CPU), input/output modules, and associated power supplies.[4] In general the three components of the CPU are the microprocessor, the logic memory, and the storage memory. Figure 1. contains a schematic block diagram of a typical PLC system. Logic memory contains storage of the instructions that result from execution of the ladder diagram logic. These instructions guide the reaction of the PLC microprocessor in response to inputs such as activating or deactivating a field device or sensor. The ladder diagram logic is developed and downloaded from a programmer such as an industrial personal computer (IPC). Storage memory retains numerical values such as obtained during arithmetic or counting operations.

For successful signal transmission, input/output racks (IOR) are placed adjacent to concentrations of pumps, gate operating machines and associated sensors. These racks can be housed in free standing booths that are environment controlled or within motor/sensor control rooms (MSCRs). Hardwired signals from the field devices enter the IOR and are converted to fiber optic signals. Fiber optic signals can travel significant distances without suffering attenuation. Devices kept in the IORs include I/O modules, remote interface modules, analog input modules, fiber optic modules, relays, motor starters, data loggers, and device power supplies. Figure 2. contains a typical schematic layout of the control elements of an automated navigation lock.

Software

Several software programs and functions have been used for operation of PLC based control systems. Some of the functions are available in combined packages available from PLC vendors.

PLC based control systems can require one or more communication networks. A given communication network may involve thousands of feet of fiber optic control circuits, and twin axial monitoring cables, as well as interface modules, printers, additional IPCs, and other devices. A network manager is used to monitor, manipulate, and trouble shoot the local area network (LAN).

The ladder logic control program is executed by the PLC processors. This program is developed and loaded into the PLC using software that is available from the PLC manufacturer. One site design employed a portable personal computer to facilitate reprogramming or modification of the ladder logic control program

FIGURE 1. SCHEMATIC BLOCK DIAGRAM OF TYPICAL PLC SYSTEM.

FIGURE 2. TYPICAL LAYOUT OF PLC BASED CONTROL SYSTEM COMPONENTS

from any location in the network that contained a network interface module such as at the PLC central processing unit. Another site achieved the same capability from a remote location via modem connection.

Development of a user/operator interface is executed using any of a number of software packages recommended or supplied by PLC manufactures. In general it is preferable to program/load the PLC ladder logic and define the PLC register assignments prior to developing the user interface. A common approach observed was to develop the user interface so as to resemble the traditional look and feel of the old control console environment. Screen icons can be designed to resemble hardwired control components, switches, push-buttons, lights, and indicators. One site took the additional step of using infrared touch sensitive screens. It was found however that the operators preferred using the mouse. To conserve screen space in one design, once a "device on" switch was activated, the user interface was programmed to automatically relabel the screen icon as the "device off" switch. At another site, it was determined that each indicator light could be programmed to represent 8 different output indications dependant upon operation status.[3] Even with this much screen conservation capability, the sites examined still had many more control elements than could be displayed on one screen. It is typically necessary to configure the interface into a number of status screens. These screens ranged from lock overviews to individual valve operation displays. Displays consist of status lights, warning lights, device status readings, gate position readings, and other indicators. A lock overview screen at one site displays color and position changes of devices and gates as the real-time status and positions of these elements changes during a lock operation.

Main control consoles at different sites have been located either at upstream or downstream vantage points or in a control tower. In addition, auxiliary control consoles have been placed in booths at both ends of the lock. Each of these control consoles contains an IPC that functions as a user interface as well as a network interface for reprogramming the controller logic. Also, in the event of a PLC system failure, hard wired by pass controls have been developed by some sites - designed as portable plug in boxes deployable from any control console.

Monitoring Devices

Tools being employed to facilitate site monitoring include computer monitors, closed circuit television, fog lighting, position transducers, and other sensors. The following sections discuss the use of these devices.

As mentioned in a previous section, some sites use computer monitors to maintain a schematic display of the controlled features of the lock. The operator scans this display to obtain a real time indication of what systems, gates, or other components are active and at which process stage they are engaged. Screen representations are animated to indicate motion and position of gates. Screen representations of sensors provide analog indicators of position transducers and other sensor outputs.

Other monitors are dedicated to color CCTV displays of selected lock areas. In some cases weather sealed cameras are placed at each side of each gate on the lock wall. These observation points provide views of traffic proximity, miter gate recesses, gate bridges, slide gate positions, and other locations. In general, it has been observed that at least one monitor system is situated adjacent to each control console of a given project. In one case, the main control tower contained several color monitors mounted on the ceiling above the control system computer monitors. Cameras are keyboard or joy stick controlled with pan, tilt, and zoom capability. Some systems enable considerable display manipulation. Any camera image can be displayed onto any monitor. More than one camera image can be displayed on a single screen. For night viewing at one site, outdoor area lights were selected to provide 1-2 foot-candles of illumination.[2]

SAFETY AND SECURITY CONSIDERATIONS

While Corps of Engineers policy on lock automation is under development, a key issue is the continued safety of the personnel and users of the locks. Successes in lock automation initiatives have hinged on the delivery of cost effective lock operation without compromising the safety and security of operators, users, and locks. The following sections present some aspects of these considerations.

Personnel

Potential reductions in staffing requirements brought on by automation means that there are fewer personnel at risk. In contrast, this also means that there are fewer eyes and ears to sense problems and fewer resources to lend a hand during difficulties. Key areas of risk are the gate pedestrian bridges. It is not difficult for most sites to provide CCTV coverage to these locations to monitor for personnel or stray visitors during a locking event. Some sites are contemplating additional precautions such as installation of infrared or other sensors on the bridges. Signals from these devices could be incorporated as interlock features of the ladder logic program. In general, all the safety interlocks that are typical of hard wired controls can also be incorporated into the ladder logic program.

Lock Gates

Inside the lock, the potential for barge collisions to the lock gates is partially associated with communication miscues between the tug operator and the tow hands. These collisions could be mitigated by providing the tug operator with green, yellow, red indicator lights that could be activated by the PLC in response to sonar or sensor feeds. Alternatively, a large screen monitor located within each control booth and displaying the CCTV feed at each end of the lock could provide the same function. Research being conducted at the U.S. Army Construction Engineering Research Laboratories is examining these new sensor technologies.[5]

PLC Equipment

Access to operator interfaces are guarded with pass word protected log-ons. Installation and periodic upgrade of virus protection software is advisable especially if any of the network computers are used for other applications or where internet access is maintained. Appropriate cable shielding and other actions may need to be taken due to possible radio frequency interferences and instrument cross talk. Optical isolation of devices is recommended to protect against lightning or other power surges.

PROCUREMENT CONSIDERATIONS

In procuring an automated PLC based control system several issues need to be addressed. Site managers have developed strategies that yield viable systems. The following sections describe some of these winning strategies.

Equipment Selection

In successful initiatives care was taken to ensure that all the hardware in the network was compatible with each of the software packages in use. Personal computers were selected with expandable memory and operation capabilities to facilitate future upgrades. These procurements also included extensive spare parts inclusive of extra CPU boards, video controller cards, hard drives, and other components that may require quick replacement.

Programming and Training

Site personnel received factory or qualified contractor supplied training on the use of the network instrumentation. The graphical user/operator interfaces were designed to make the PLC system transparent to the operator. Programming of the ladder logic was conducted or closely guided by district engineers. Similarly, the user interfaces were designed and programmed by district engineers in coordination with site operators and staff. For this purpose it is advisable to have a contractor train members of the engineering staff in the use of the ladder logic development software as well as the graphical user interface development software. Where resources are not available for in house programming the contract can be configured to require both factory and on site training of site personnel.

Testing

Successful procurements may involve several stages of equipment and system testing. Factory testing of all personal computers and connections is performed to ensure operability of the network. On site testing of the personal computers is repeated after all the hardware has been installed in the permanent consoles and other locations. Each input and output in each IOR is checked and verified in the factory.

In one case, the contractor was required to assemble a lock simulator in the factory to provide training to site personnel.[2] After factory testing and training, the simulator was delivered to the site and reassembled in a building on site where operation was rechecked and site personnel were allowed to practice operations for an extended period.

Installation

Successful system installations are conducted with factory personnel and contractors on site. All input and output connections in the IORs and the network are reverified. IOR connections are double checked utilizing the graphical user interface simultaneously as all other system software is rechecked on site.

Resources

Engineering Technical Letter ETL 1110-2-553 entitled "Control Stations and Control Systems for Navigation Locks and Dams" provides engineering and design guidance on the layout of control structures and the use of PLC systems.[6] Another resource that will be available in FY99 is Engineering Manual EM 1110-2-2610 entitled Gate Operating Equipment for Navigation Locks and Spillways.[7] This document will contain a section on control that will provide detailed engineering and design guidance on automated and PLC based control systems for navigation locks.

SUMMARY

The automation of navigation locks is an emerging area with successful projects under way. Realization of viable automated projects requires that site managers recognize the technical, safety, procurement, and training issues that influence these operations. Projects equipped with high performance eyes and ears are being used to operate these facilities with increased efficiency. Programmable logic controller systems running on fiber optic transmission networks enable site operators to control more elements with fewer personnel resources. Meanwhile it appears that future advances in sensing technologies may further enhance the safety and efficiency of automated navigation projects while enabling reductions in resource requirements.

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